# SkySync:
## A Personal Weather Station

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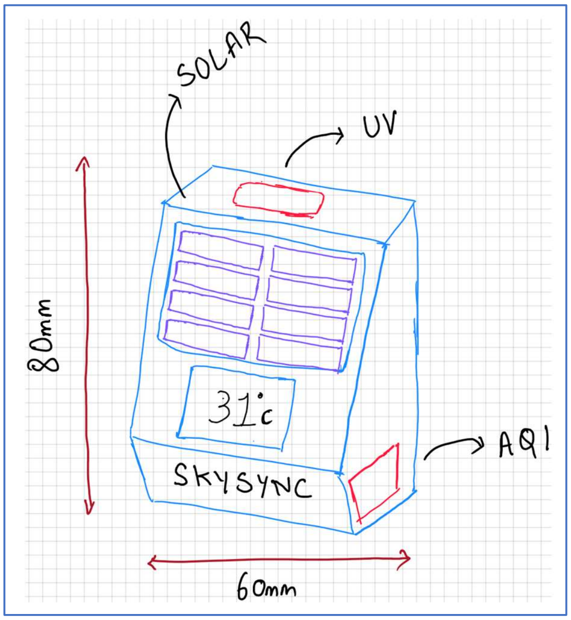
# SkySync: A Personal Weather Station

In today's rapidly evolving data-centric ecosystem, data isn't just pivotal – it's transformational. Our ability to make informed decisions, whether in our personal lives or professional domains, largely rests on the accuracy and timeliness of the data we collect. Enter SkySync, a personal weather station tailored for the modern user. Unlike traditional weather stations which are fixed and bulky, SkySync is portable, user-friendly, and designed to seamlessly integrate with your daily activities.




*1: Napkin Sketch of how it might look.*

## Unique Value Propositions

- **On-the-Go Environmental Intelligence**: Whether you're an outdoor enthusiast embarking on a hike or a biker embracing the wilderness, SkySync can be effortlessly attached to your backpack, ensuring that you're always aware of the environmental conditions around you. Tracking metrics like UV Exposure (UVA, UVB, UVC), Air Quality ($eCO_2$, VOCs), temperature, pressure(altitude) & humidity.
- **Indoor vs Outdoor Comparative Analysis**: Why rely on generic weather reports when you can measure real-time indoor conditions and juxtapose them with the outdoors? With SkySync, you gain insights into how external weather impacts your indoor environment, allowing for optimized comfort and energy savings.
- **Geo-Tagged Data Collection:** With an integrated companion app, every data point SkySync captures is geo-tagged. This not only allows users to understand climatic variations across different terrains and locations but also allows creation of a rich database for deeper environmental analysis.
- **Sustainable Energy:** SkySync incorporates solar cells for energy harvesting. This ensures extended usage without the need for frequent recharges, and more importantly, minimizes the carbon footprint.
- **Personal Safety Alerts**: Beyond just data collection, SkySync offers actionable insights. If a sudden drop in temperature is detected or a storm seems imminent, SkySync, via its companion app and hardware features like beeper, will send real-time alerts ensuring you're never caught off guard.

# Block diagram

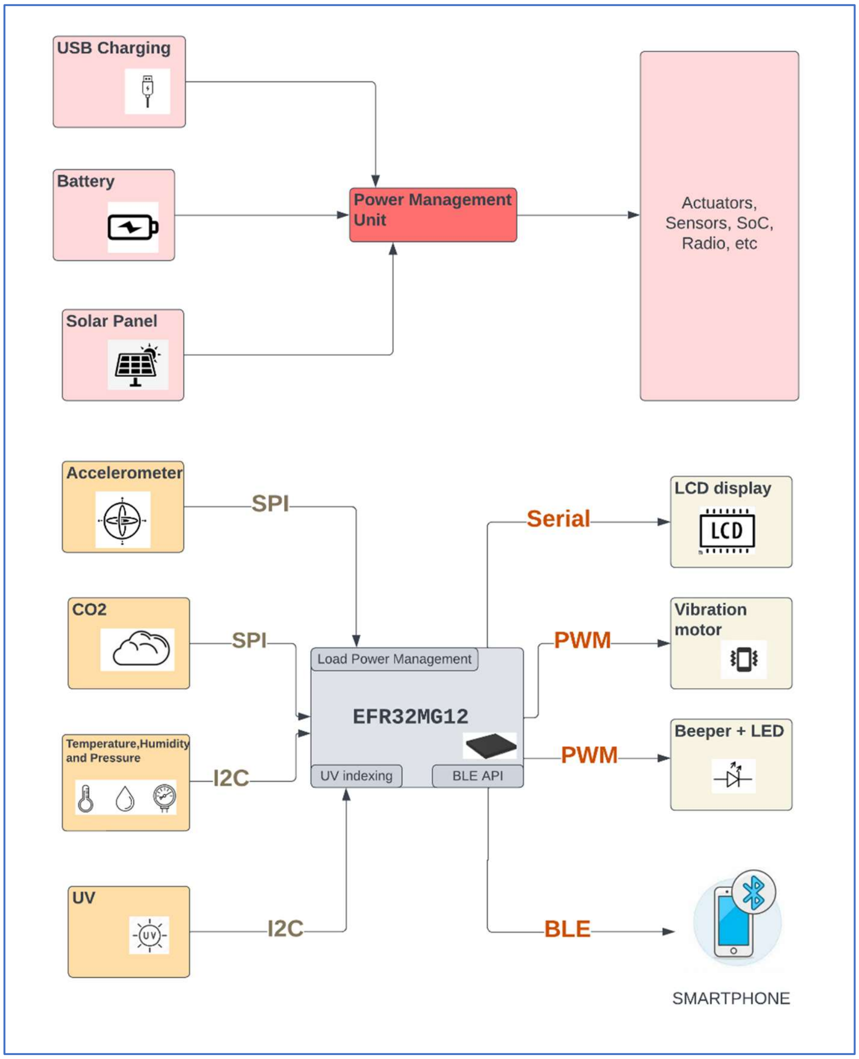



*Figure 2 System Block Diagram*

This complex EFR32MG12 SoC-based system serves as a sophisticated environmental monitoring platform. It amalgamates data from ENS160, BME280, and AS7331 sensors to provide comprehensive insights into air quality, weather conditions, and UV radiation exposure. Users can access this data through a low-power LCD display or remotely via a smartphone connected through BLE. Additionally, the vibration motor enhances user interaction by providing tactile feedback or alerts, contributing to a holistic and user-friendly experience.

# Product Features

**Air Quality Index (AQI)**: The ENS160 sensor will be integrated into our weather application to provide real-time air quality data. Users can access up-to-the-minute air quality information, allowing them to make informed decisions based on the latest data. When used in combination with other data, such as CO2 and VOC levels, the ENS160 sensor can contribute to assessing indoor air quality, which is important for occupant health and comfort.

**UV Index**: The AS7331 is a low-power, low noise integrated UV sensor. A "Spectral UVA/B/C Sensor" typically refers to a sensor that can measure different segments of the ultraviolet (UV) light spectrum, specifically UVA, UVB, and UVC. The three separated UVA, UVB and UVC channels convert optical radiation signals via photodiodes to a digital result and realize a continuous or triggered measurement.

**Load power management**: We will be utilizing the MC3419 accelerometer to assess user activity through linear motion, and we are dynamically adjusting the product's measurement frequency based on detected activity levels to optimize data collection and power efficiency. During more intense activities like hiking, the station measures data more frequently and provides it to the user. More intense activities usually entail faster dynamic weather environments.

**Temperature, Humidity and Pressure**: In our weather station project, we will integrate the BME280 sensor to precisely measure temperature, barometric pressure, and humidity levels in nearby surroundings. This sensor enables us to provide accurate and real-time meteorological data, enhancing the reliability and functionality of our weather monitoring system.

**Smartphone app**: We're employing Bluetooth Low Energy (BLE) technology to seamlessly transmit real-time weather data from our monitoring station to nearby smartphones. This wireless connection allows users to conveniently access up-to-the-minute weather information on their local smartphone, enhancing their ability to make informed decisions based on current environmental conditions.

**Haptic feedback**: We will integrate a vibration motor into our system to provide timely alerts to users in the event of adverse weather conditions or deteriorating air quality. This haptic feedback mechanism ensures that users are promptly notified of critical environmental changes, enhancing their safety and awareness.

**Display**: We're incorporating a low-power LCD display (Sharp 128x128 LS013B7DH03) into our weather station to efficiently showcase real-time weather data at periodic intervals. This energy-efficient display ensures that users can effortlessly access up-to-date meteorological information while maximizing battery life in our portable weather monitoring solution.

# Product Specifications

- **$CO^2$**: Measure VOCs and Carbon Dioxide between Excellent conditions (~400 ppm) to Bad conditions (>1500 ppm) with accuracy of ±15%.
- **Ultraviolet**: UV Index from 1-11+ according to Erythermal Action Curve.
- **Battery Life**: Up to 12 hours of active mode battery life on a single charge, up to 72 hours in low power mode.
- **Activity detection**: Detect and distinguish between low activity levels and high activity levels to better manage energy.
- **Temperature and Pressure:** Measures temperature from the range -40°C to 85°C with accuracy of ±0.5°C and pressure from the range below sea level (300 hPa) to Mt. Everest (1100 hPa) with accuracy of ±2 hPa.
- **Connectivity**: Sync to smartphone app over BLE with range of up to 10 mts.

# Extended Features and Stretch Goals

These are some of the additional hardware, firmware & software features we want to implement based on project timeline and challenges.

- **NFC Quick Pairing:** Using passive or active NFC tags, implementing quick BLE pairing using NFC as OOB data.
- **PM2.5 Particulate Matter Measurement**: Particulate Matter addon sensor which can be attached to the main device for improved AQI numbers.
- **Swappable Solar Panel**: Swap to a bigger solar panel when device is stationed.
- **Additional App Features:** Notifications on App, GPS tagging and additional visualization.
- **Cloud Dashboard:** Data storage on cloud and visualization.
- **User Button:** Cycle through all the metrics on the display.
- Simultaneous App Communication with multiple portable weather stations.

# Challenges

**Miniaturization**: Designing compact and portable weather monitoring equipment that houses multiple sensors while maintaining accuracy can be challenging. The nature of sensors, for example UV sensor, which requires a wide field of view to capture the incoming light, will put constraints on the layout of the board. It cannot be placed next to bulky components which limit its view. The solar cells also have similar requirements. This poses a challenge in being able to place all components on the PCB without compromising any of their functionality.

**Power Management**: Our portable weather stations run on batteries and solar energy. Additionally, due to moving parts (vibration motor) and the nature of some exotic sensors (UV sensor) the peak current drawn at times could come very close to, or exceed, the max current pushed by the PMIC. Balancing power efficiency with data accuracy is a challenge.

**UV**: In our research, we found a sensor which gives us UV A, B and C spectral values. But this is not equivalent to the UV index that can be readily used. It would be a challenge to map these spectral values to the UV index and thus determine the harmful range.

**Sensor Calibration**: Ensuring the accuracy of sensor readings is essential for a weather station. Calibrating sensors like UV sensor and CO2 sensor and maintaining calibration over time due to sensor aging can be challenging, as environmental conditions can affect sensor performance.

**Data Transmission**: Transferring data from the product to a local smartphone poses challenges in terms of pairing and maintaining BT connections. As the BLE radio consumes power for every transmission, finding the sweet spot between conserving energy and providing the user data regularly becomes critical.

**Environmental Protection**: Weather stations need to withstand various environmental conditions, including rain, humidity, and temperature extremes. Designing a robust and weather-resistant enclosure is crucial for long-term outdoor use. A 3D printed case with adequate protection might be necessary.

**Cost Management**: Weather has a lot of parameters, and each factor needs a sensor of its own to measure it. Developing a portable weather station with high-quality sensors and features can be expensive. Additionally, we will have to make choices between going for a more critical environment factor for a costlier sensor versus going for multiple less-impactful environmental factors with cheaper sensors.

**Testing and Validation**: Rigorous testing and validation under different weather conditions is necessary. Figuring out a way to simulate these conditions, without causing any harm to any member of the team, will be tricky. Fortunately, residing in Boulder, CO, we experience all sorts of weather conditions and that makes this challenge slightly easier to navigate.

# Component Selection and Specifications

| SYSTEM FUCNTIONS | COMPONENT | WEBSITE LINK | DATASHEET & Digikey Part Number | Dimension | COST |
|---|---|---|---|---|---|
| **SoC** | MIGHTY GECKO | EFR32MG12P432F1024GM48-C | DATASHEET 336-4227-ND | 7mm x 7mm | 11.79 |
| **BATTERY** | LI-ON BATTERY | ASR00036 | DATASHEET 1832-1052-ND | 48.0mm x 30.0mm x 6.0mm | 6.37 |
| **ENERGY HARVESTING** | SOLAR CELL | SM111K10L | DATASHEET SM111K10L-ND | 42.0mm x 35.0mm x 2.0mm | 9.39 |

| SYSTEM FUCNTIONS | COMPONENT | WEBSITE LINK | DATASHEET & Digikey Part Number | Dimension | Interfaces | Current/Power Consumption | Operating voltage | COST (USD) |
|---|---|---|---|---|---|---|---|---|
| **SENSORS** | MC3419<br>*Backup (ADXL343) | MC3419 | DATASHEET3502-MC3419CT-ND | 2 mm × 2 mm × 0.92 mm | I2C SPI | • Standby current 4 µA<br>• WAKE state current 77 µA | 1.7 V to 3.6 V | 1.66 |
| | BME280 | BME280 | DATASHEET828-1063-1-ND | 2.5 mm x 2.5 mm x 0.93 mm | I2C SPI | • 1.8 µA @ 1 Hz humidity and temperature<br>• 2.8 µA @ 1 Hz pressure and temperature<br>• 3.6 µA @ 1 Hz humidity, pressure and temperature<br>• 0.1 µA in sleep mode | 1.71 V to 3.6 V | 6.42 |
| | ENS160 | ENS160 | DATASHEET2618-ENS160-BGLMCT-ND | 3 mm x 3 mm x 0.9 mm | I2C SPI | • DEEPSLEEP mode 0.01 mA<br>• IDLE mode 2 to 2.5 mA<br>• STANDARD mode 29 mA | 1.71 V to 1.98V | 10.2 |
| | AS7331 | AS7331 | DATASHEET4991-AS7331_MOLGA16LFT&RDPCT-ND | 2.6 mm x 3.65 mm | I2C | • Active mode during measurement 1.5to 2 mA<br>• Standby state 970 µA<br>• Power down state 1 µA | 2.7 V to 3.6 V | 10.8 |
| **ACTUATORS/ OUTPUTS** | DISPLAY | LS013B7DH03 | DATASHEET425-2903-ND | 23.0 mm x 23.04 mm | Serial | • 12-130 uW | 2.7 V to 3.3 V | 11.9 |
| | VIBRATION MOTOR | VCLP1020B002L | DATASHEET1670-VCLP1020B002L-ND | Dia (10.00mm) | | • Max 30 mA | 2.5 V to 3.5 V | 2.12 |

# Project Week 1 Update

## Status report

After receiving feedback from the Professors and TAs, we finalised the SOC and sensors. By moving the accelerometer and vibration motor as our stretch goals, we decided to reduce the complexity. Moreover, we are leaning towards the BG22 series since our application is only BLE based. We have also created a common git repo to keep track of the tasks scheduled and upload the work done.

**Upcoming Activities:**

- We will work and research on Battery and power management selection next week.
- Order modules for preliminary SBB testing.

As per the schedule assigned by the professor at the beginning of the project, and timeline planned by us, we are on track. We do not have any hurdles at this point, but we do foresee some as we dig deeper into our project design. The TAs have been guiding us as and when necessary for all project planning activities.

## Use Case model

Every sensor data point is sampled every X minute, data is processed and sent over BLE to the Central Device (smartphone). Hence, every $X^{th}$ minute the SoC will wake up from deep sleep mode (EM2) and be awake (EM0) for a certain duration, enough to read data from the sensors and transmit it to the central device, and then go back to deep sleep. This constitutes one read and transmit cycle. This repeats every $X^{th}$ minute. For this calculation we have assumed X to be 10 minutes. This assumption is just to get a rough idea of energy consumption.

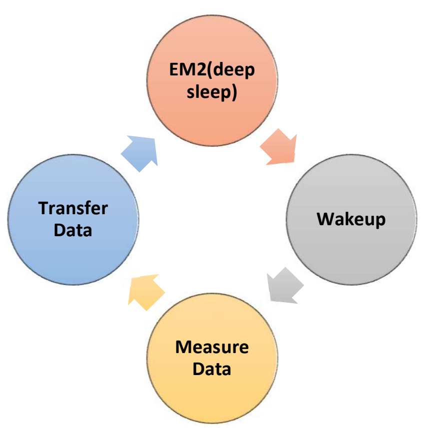
This use case model will be further developed as we develop the features further to determine optimal sampling rates and user inputs. According to our current estimates, the sensor sampling will cycle between 5, 10 and 20 minutes. This gives the user the option of using our product in dynamically changing environments.

As of now it is assumed that all sensors are measured once in 10 minutes. For the actual implementation different sensors might be measured at different intervals. It makes more sense to measure Temp/Pressure/Humidity and UV more frequently compared to AQI. TBD based on the final application.

Worst case average current consumption has been assumed for the SoC based on the previous currents measured for IoT course projects. This was more realistic than using datasheet numbers.

Currently, we also assume that the measurement cycle repeats indefinitely.

Assuming a 10-minute cycle, 30s in EM0(run) mode and 570s in EM2(deep sleep) mode with Radio on. Below is simple state diagram of all the states the SoC cycles through, in our project. This is cyclic for every read and transmit cycle.



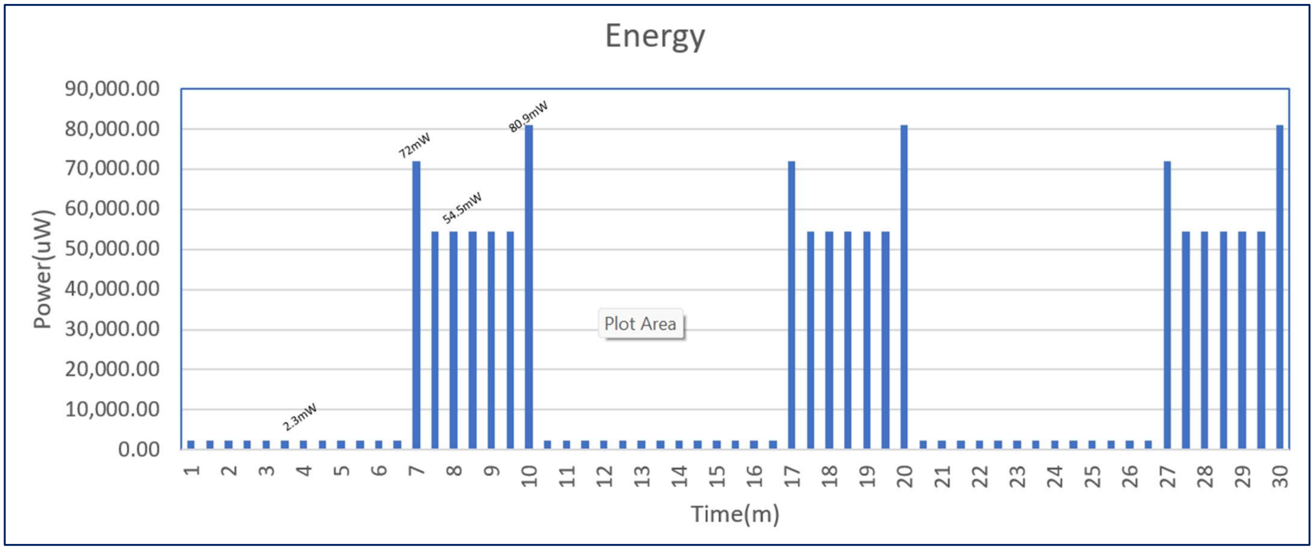
## Part selection of all major components

| COMPONENT | SPECIFICATIONS/FEATURES |
|---|---|
| EFR32BG22C224F512GM32-C | • Features a high-performance 32-bit ARM Cortex-M33 processor, running at 76.8 MHz.<br>• Offers up to 512 kB of flash program memory and up to 32 kB of RAM data memory.<br>• Supports 2.4 GHz radio operations. |
| LI-ON BATTERY | • Rechargeable battery with a capacity of 850 milliampere-hours (mAh).<br>• Nominal voltage of 3.7V.<br>• Discharge Cut-off Voltage is 2.4V. |
| SOLAR CELL | • Monocrystalline silicon technology.<br>• Typical voltage is 5.58 V, and a current is 43.9 mA at the point of maximum power (Pmpp).<br>• Short-circuit current (Isc) of 46.7 mA and Open-circuit voltage of 6.91 V. |

## Sensor/actuator selection

| SENSOR | REASON OF SELECTION/FEATURES |
|---|---|
| **ENS160** | • **Provides multiple indoor air quality (IAQ) metrics: TVOC, eCO2, AQI.**<br>• Compatible with both I2C and SPI communication interfaces. |
| **AS7331** | • **Allows for distinct measurements of UVA, UVB, and UVC radiation, providing comprehensive UV data.**<br>• Supports the use of up to four AS7331 sensors simultaneously on the same I²C bus, allowing for versatile UV monitoring setups.<br>• Designed for low-power operation and includes power management features such as Power-on Reset, Power-down, and standby modes.<br>• Employs three separate UV detectors with interference filter technology, enabling precise measurement of UVA, UVB, and UVC radiation |
| **BME280** | • **Widely used and combines multiple environmental sensors in a single compact package, including a barometric pressure sensor, a humidity sensor, and a temperature.**<br>• Supports I²C communication at speeds of up to 3.4 MHz and SPI communication with both 3-wire and 4 wire modes at speeds of up to 10 MHz.<br>• Flexibility to independently enable or disable the humidity sensor and pressure sensor. |

# Energy mode bar chart




As mentioned in our use case, a 10-minute cycle has been assumed for the intent of power calculations. The system is in deep sleep (EM2) mode. At the 7$^{th}$ minute, the system wakes up to trigger a measurement of ENS160's sensor data. This is done as the sensor needs about 3 minutes to produce valid data. Hence, there is a small peak at the 7th minute. The SoC is in EM0 mode and the ENS160 is turned on and is in measurement mode. After triggering the measurement, via I2C, the SoC goes back to sleep mode and hence the slight drop in power. From the 7$^{th}$ minute to 9.5$^{th}$ minute, the system does not have any task at hand and goes back to deep sleep. At the 9.5$^{th}$ minute, the system wakes up for the following tasks:

- Read data from the ENS160 sensor, which we triggered previously.
- Trigger and read data from the BME280 as well as AS7331 sensors, via SPI and I2C respectively.
- Make necessary data processing and alert user.
- Transmit data over Radio to a central device, here smartphone.

During this period, the system will be consuming max current. After successful transmission, the system goes back to deep sleep mode. End of one measurement cycle. This repeats indefinitely.

# Power Calculations

### SoC

Assuming a 10-minute cycle, 30s in EM0 mode and 570s in EM2 mode with Radio on

EM2 - Full RAM retention and RTC running from LFRCO in precision mode.

| State | Current (mA) | Power (mW) | Weight |
|---|---|---|---|
| EM2 | 0.7 | 2.31 | 0.95 |
| EM0 | 6 | 19.8 | 0.05 |

Weighted Average of Current = **0.965mA**, at 3.3V Weighted Average Power = **3.1845mW**

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### BME280 Humidity, Temperature, Pressure

In weather monitoring mode.

| State | Current (mA) | Power | Weight |
|---|---|---|---|
| Deep Sleep | 0.0001 | 0.33 uW | 0.98 |
| Active | 0.7 | 2.31mW | 0.02 |

Needs about 8ms to wake up and measure data.

Considering one data measurement every 10 minutes.

Weighted Average Current = **0.01437mA**, at 3.3V Weighted Average Power = **0.0474mW**

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### ENS160 AQI, eCO2, TVOC

| State | Current (mA) | Power | Weight |
|---|---|---|---|
| Deep Sleep | 0.01 | 18 uW | 0.7 |
| Active | 29 | 52.2 mW | 0.3 |

The sensor needs 3 minutes to warm up, considering one measurement every 10minutes As of now we are assuming that this sensor will be powered at 1.8V using an LDO.

Weighted Average Current = **8.7mA**, at 1.8V Weighted Average Power = **15.66mW**

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### AS7331 UV Index

| State | Current (mA) | Power | Weight |
|---|---|---|---|
| Deep Sleep | 0.001 | 3.3 uW | 0.98 |
| Active | 2 | 6.6 mW | 0.02 |

Needs about 70ms to wake up and measure data.

Considering one data measurement every 10 minutes.

Weighted Average Current = **0.0401mA**, at 3.3V Weighted Average Power = **0.13233mW**

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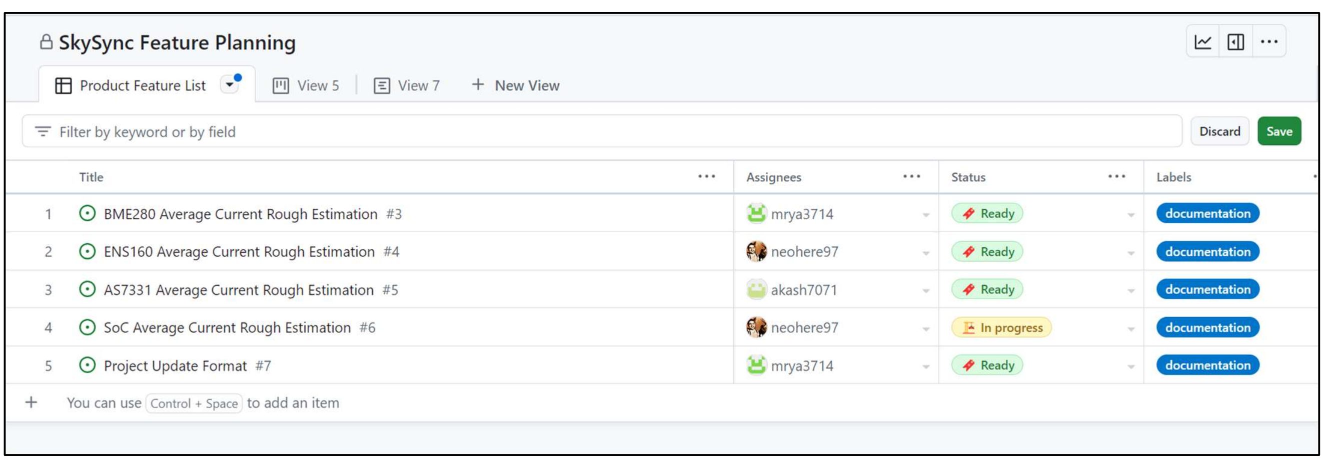
### Combined Average Current and Power

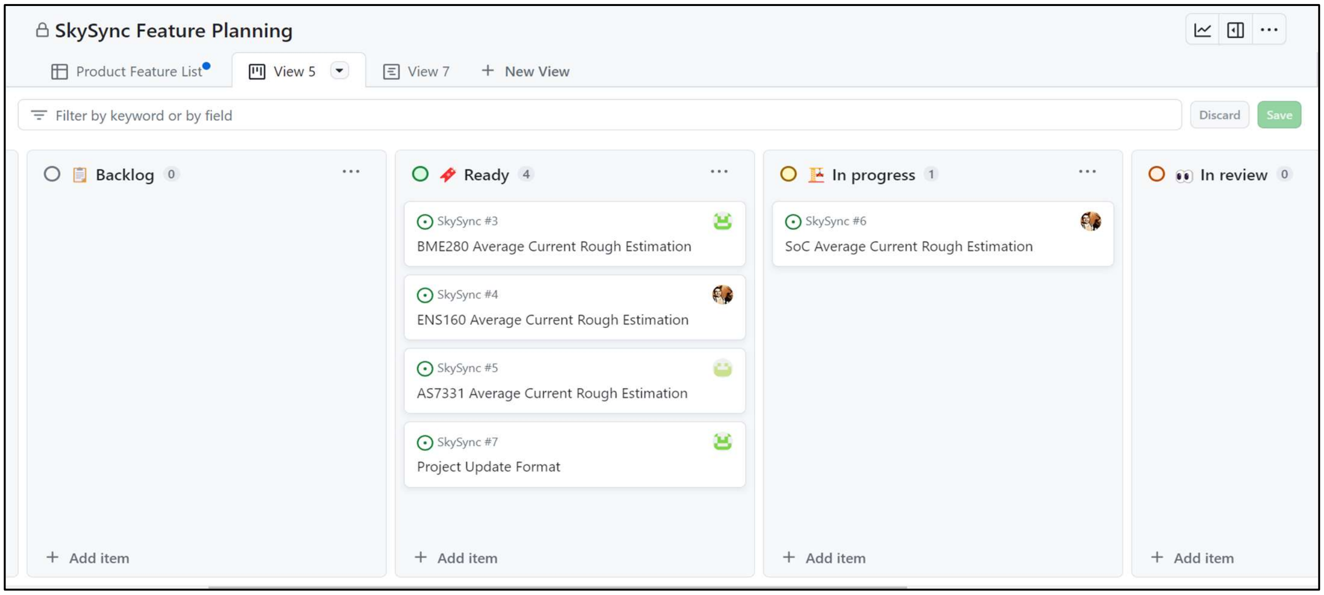
| Device | Avg Current (mA) | Voltage (V) | Avg Power (mW) |
|---|---|---|---|
| EFR32 BLE SoC | 0.965 | 3.3 | 3.1845 |
| BME280 | 0.0143 | 3.3 | 0.0474 |
| AS7331 | 0.401 | 3.3 | 0.1323 |
| ENS160 | 8.7 | 1.8 | 15.66 |
| **Total** | -- | -- | **19.024** |

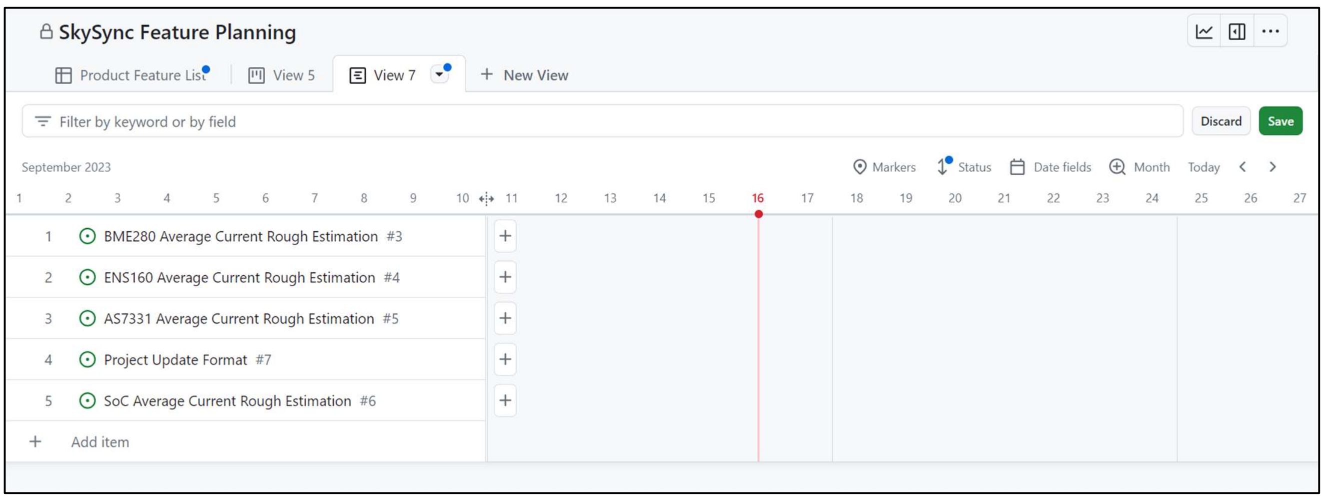
# Gantt chart demo

Created a Gantt chart on GitHub. The left side outlines a list of tasks, assignees, status, markers with schedule that visualize work.

[Github Gantt chart]






# Miscellaneous Updates

- LGA package PCB footprint designing for ENS160.

# Project Week 2 Update

## Status report

With further discussion on Power Management Units and Energy Storage Elements, a decision has been made on the usage of Li-Po batteries over super capacitors. With effective collaborations with the SAs, it has been decided to move ahead with BQ25570 as our PMIC, which dons the role of energy harvesting IC, Battery Management Unit as well as buck and boost converters. A versatile PMIC reduces the need of additional components on the board. Additionally, 3.3V has been decided to be powering all the components on the board, after considerations on the heat generation and additional circuitry involved with LDO circuits to step down to 1.8V. A few course-corrective measure have been taken from the previous update as well as feedback received from the Project update.

Project is on schedule and regular feedback from professors and assistance from the SA team has been vital to that. Expecting roadblocks soon, especially for the assumed parts of the project.

**Upcoming Activities:**

The coming week has a lot of development and testing.

- The dev kits and the sensor modules will be received by us, and developing isolated circuits for sensor measurement will be the primary focus.
- Additionally, usage of shared vs separated I2C SPI busses will be tested and validated.
- Some software elements like timers, external interrupts, etc for the EFR32BG22 will be developed and tested with corresponding sensors.
- We will work and research on Battery and power management selection next week.
- Order modules for preliminary SBB testing.

As per the schedule assigned by the professor at the beginning of the project, and timeline planned by us, we are on track. We do not have any hurdles at this point, but we do foresee some as we dig deeper into our project design. The TAs have been guiding us as and when necessary for all project planning activities.

## Energy Storage element selection

One of the sensors in our application consumes about 29mA of current constantly for 3 minutes straight. This means the average current of the system is quite high and will require more energy for the expected duration of usage. Due to higher energy storage requirements and charging efficiency of Lithium-Ion Polymer batteries over Super capacitors, we decided to go ahead with the former, for our product. Below are some reasons behind our selection of ASR00036 Li-ion Polymer 850mAh Battery for our energy storing needs.

**Size**: coming in at 48mm, perfect for our application. It is small enough in size to fit onto our board and be portable and still large enough to power our system for sufficient duration.

**Voltage rating**: With maximum charging voltage at 4.2V and nominal voltage at 3,7, it will serve all our power needs. Especially the high current consuming ENS160 sensor.

**Current rating**: With Peak current at 0.5C or 425mA, our system will be able to draw 41mA, its peak current, without breaking a sweat.

**Capacity**: Based on our calculation, the 850mAh capacity will outlast our predicted 12-hour battery life. Even accounting for the battery degradation, our product will deliver the expected battery life with ~85% loss in battery capacity.

**Operating environmental conditions**: For a weather application, the physical capabilities of the battery are of utmost importance. We have chosen a battery which can withstand up to -10 ◦C when store and deliver accurate results between 0 ◦C to +45 ◦C.

# Average current calculation

**System-On-Chip:**

| State | Current (mA) | Power (mW) | Weight |
|---|---|---|---|
| EM2 | 0.7 | 2.31 | 0.95 |
| EM0 | 6 | 19.8 | 0.05 |

*Weighted Average of Current = 0.965mA, at 3.3V Weighted Average Power = 3.1845mW.*

**BME280 Humidity, Temperature, Pressure:**

| State | Current (mA) | Power | Weight |
|---|---|---|---|
| Deep Sleep | 0.0001 | 0.33 uW | 0.98 |
| Active | 0.7 | 2.31mW | 0.02 |

*Weighted Average Current = 0.01437mA, at 3.3V Weighted Average Power = 0.0474mW.*

**ENS160 AQI, eCO2, TVOC:**

| State | Current (mA) | Power | Weight |
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| Deep Sleep | 0.01 | 18 uW | 0.7 |
| Active | 29 | 52.2 mW | 0.3 |

*Weighted Average Current = 8.7mA, at 1.8V Weighted Average Power = 15.66mW.*

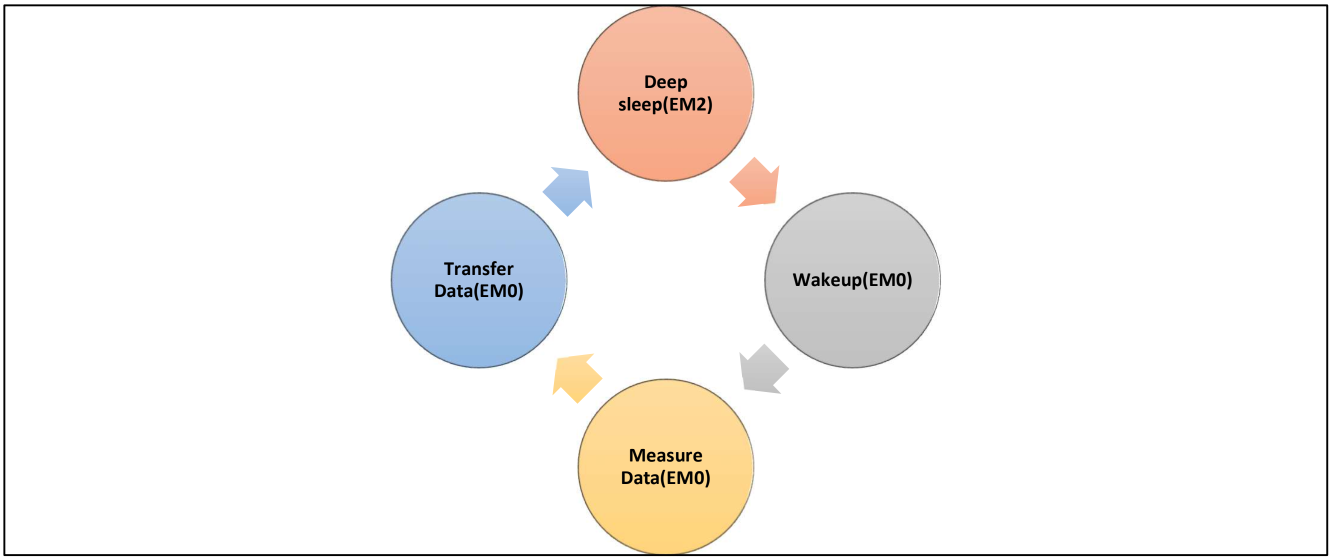
**AS7331 UV Index:**

| State | Current (mA) | Power | Weight |
|---|---|---|---|
| Deep Sleep | 0.001 | 3.3 uW | 0.98 |
| Active | 2 | 6.6 mW | 0.02 |

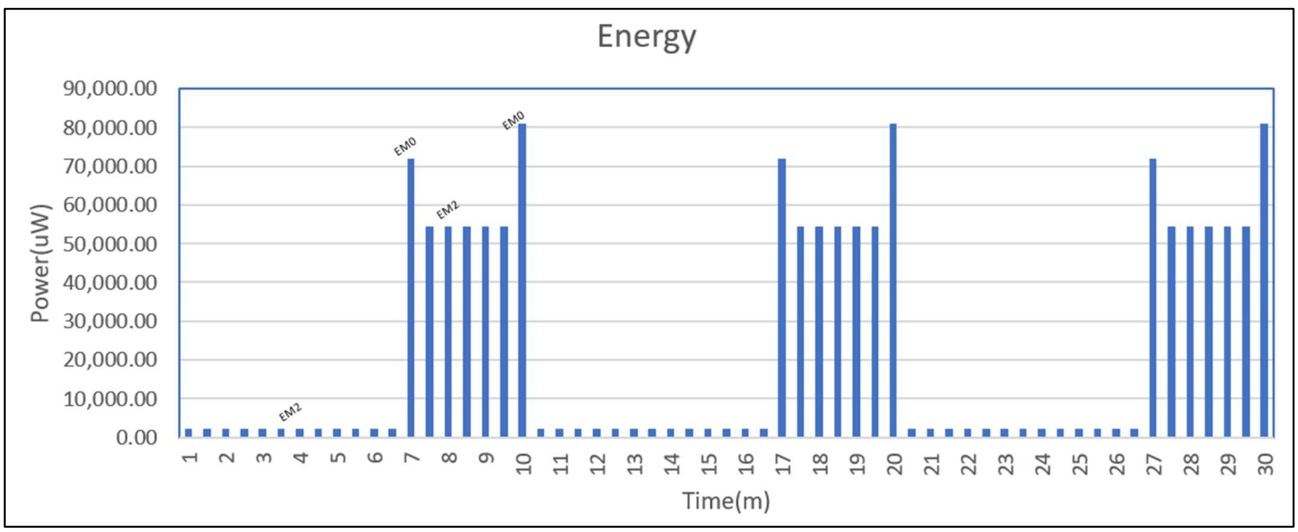
*Weighted Average Current = 0.0401mA, at 3.3V Weighted Average Power = 0.13233mW.*

## Use Case and their modes.

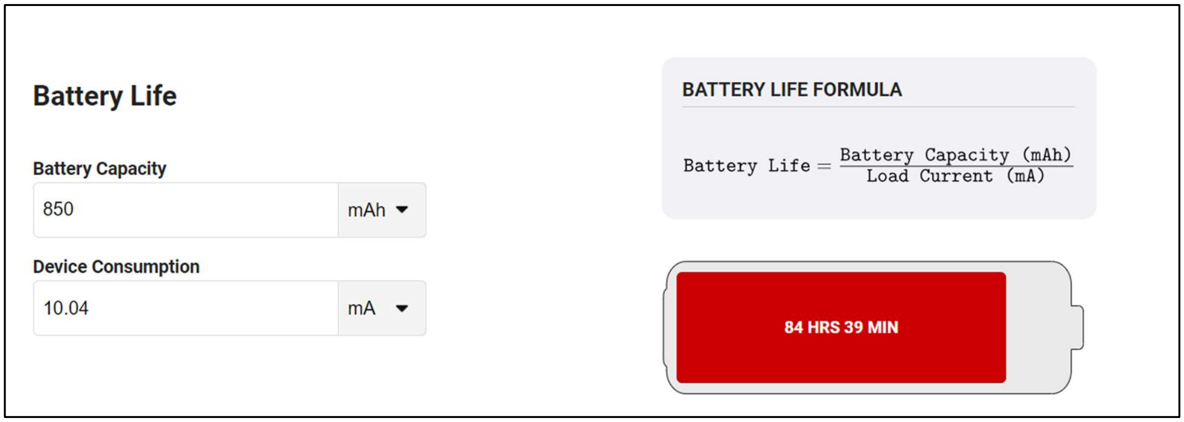
Our product is mainly run in two different energy modes EM0 and EM2. Assuming a 10-minute cycle, it operates for 30s in EM0(run) mode and 570s in EM2(deep sleep) mode with Radio on. Below is simple state diagram of all the states the SoC cycles through, in our project. This is cyclic for every read and transmit cycle.




During the EM0, the SoC will wake up sensors, initiate measurements, read data after measurements and transfer via Radio to a local smartphone. It is obvious that this is where peak current is consumed. The system goes to EM0 twice. Once to wake up a sensor, which has a 3-minute measurement period, and the second time for rest of its operations.




Accounting for a 10-minute cycle, the average current consumed is 10.04 mA, arrived at by adding up average currents from individual components. The Battery we chose delivers 850mAh on one full charge. Below is an estimate of the battery runtime when used as a energy storage element in our product.




At 84 Hrs and 39 Min, the battery life from one full charge is ~7x of our needs which is specified at 12 Hours. As per the datasheet of the Li-Ion Polymer battery we chose, the battery will retain >85% of its minimum capacity.

### 3.2 Electrical Performance

| Item | Measuring Procedure | Requirements |
|---|---|---|
| Cycle Life (25℃) | First charge with a constant current of 0.5C to 4.2V and a constant voltage of 4.2V until the charge current is less than or equal to 0.01C. Leave it aside for 10 minutes. Then discharge to 2.75V with a current of 0.5C - leave it aside for another 10 minutes. Repeat the above steps 300 times. The capacity of the cells should be higher than 80% of the minimum capacity. | Cycle life $\geq$ 300 cycles |

An average working day is about 9 hours. Considering commuting and other errands in a day, an average person is expected to be outside/ away from the reach of a charging station at the max of 12 hours. We will assume that an average consumer uses the product for 12 hours a day on the stretch. On a new battery, that should give us about 7 days of usage over a single charge.

For a 10-minute read and transfer cycle, with a 12-hour continuous operation under optimal environment conditions, the max usage of the weather station on a single full charge, ideally, can be calculated as follows.

***Max usage (in days) = Total possible hours of operation/ Use case (in Hrs.)***

*= 84 Hrs. 39 Min/ 12 Hrs.*

***= ~7 Days***

With a 7 days recharging cycle, and a 300-cycle battery degradation constraint, at the end of 300 life cycles, the product would have been in operation for 300x7=2100 days or 5.75 Years. At the end of 5.75 years, the battery capacity would be about 720mAh. This is beyond product lifecycle.

***Total energy required between charging (E) = V * I * t***

- *V = Voltage at which this energy is consumed*
- *I = average current at which the energy source is consumed*
- *t = time for which energy is consumed*

*E = 3.7V * 10.04 mA * 12 Hours*

***E = 1604 J***

Hence, over a 12-hour window our product would consume 1.6kJ of energy.

Charging Time: The ASR00036Li Li-ion Polymer 850mAh Battery supports up to 0.5C of charging speeds over traditional USB interface. At 425mA per hour, the battery would take up to 2 hours ideally to go from 0-100%.

***Charging Time (in hours) = (Battery Capacity in Ah) / (Charge Current in A)***

*= 850/ (0.5*1)*

***= 2 Hours***

This is a simplified calculation, and the actual charging time may vary slightly due to factors like charging efficiency, initial battery voltage, and the charger's characteristics.

# PMU selection

We are going to use Solar module for energy harvesting and LI-ON battery cell for energy storage. Circuitry will be operated within 3.6V – 4.2V battery voltage range.

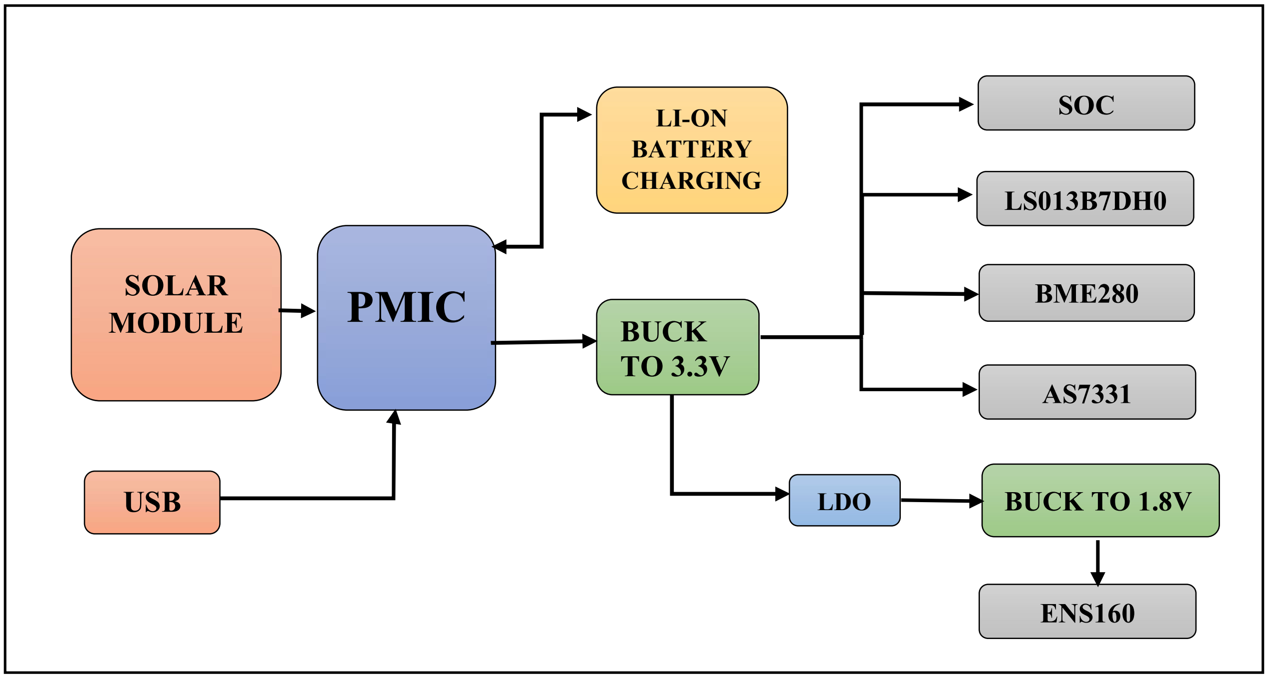
### Factors considered for the selection for Solar module and battery cell:

| COMPONENT | Important Features | Website Link | Datasheet & Digikey Part number |
|---|---|---|---|
| **SOLAR CELL (Energy harvesting)** | • VOC open circuit voltage 6.91 V<br>• ISC short circuit current 46.7 mA<br>• Vmpp voltage at max. power point 5.58 V<br>• Impp current at max. power point 43.9 mA | SM111K10L | DATASHEET<br>SM111K10L-ND |
| **LI-ON BATTERY (Energy storage)** | • Nominal Voltage 3.7 V<br>• Charge Voltage 4.2 V<br>• Cut-off Voltage 2.4 V | ASR00036 | DATASHEET<br>1832-1052-ND |

### Module requirements and features considered:

| COMPONENT | Minimum Vinmax | Maximum Vinmin | Planned Voltage supply |
|---|---|---|---|
| **EFR32BG22C224F512GM32-C** | 1.71 | 3.8 | 3.3 |
| **ENS160** | 1.71 | 1.98 | 1.8 |
| **AS7331** | 2.7 | 3.6 | 3.3 |
| **BME280** | 1.71 | 3.6 | 3.3 |
| **LS013B7DH03** | -0.3 | 3.6 | 3.3 |

According to the supply voltage and peak output current requirements of the sensors and SOC, we designed the power management Unit.




**PMIC and LDO selection:**

| COMPONENT | Important Features | Website Link | Digikey Part number |
|---|---|---|---|
| **PMIC (BQ25570)** | • Cold-Start Voltage: VIN ≥ 600 mV<br>• Continuous Energy Harvesting from VIN as low as 100 mV<br>• Supports Peak Output Current up to 110 mA(typical) (Buck converter)<br>• Energy can be Stored to Re-chargeable Li-ion Batteries, Thin-film Batteries, Supercapacitors, or Conventional Capacitors | bq25570 | 296-37014-1-ND |
| **LDO (LP5907)** | • Input voltage range: 2.2 V to 5.5 V<br>• Output voltage range: 1.2 V to 4.5 V<br>• Can supply up to 250 mA output current (EN5160 consumes approx. 29mA in active mode) | LP5907 | 296-41463-1-ND |

We plan to use the BQ25570 boost charger for continuous energy harvesting via a solar module. The harvested energy will be stored in a lithium-ion battery. Additionally, we will utilize a buck converter within the PMIC to step down the voltage to 3.3V, which will power two sensors, a display, and the system-on-chip (SoC).

For the ENS160 sensor, it's important to note that the maximum supply voltage it can handle is 1.98V. To meet this requirement, we have decided to incorporate a Low Dropout Regulator (LDO) to configure the output voltage to 1.8V. This 1.8V supply voltage will be sufficient to power the ENS160 sensor.

Moreover, PMIC can also be operated with USB (TBD).

- Does the digital / analog portion of the board require a fixed voltage?
  Yes, for instance BME680 has a VDDIO pin which enables and disables I2C bus. It requires minimum VIH (2.64V) and VIL (0.66V) for logical high-low voltages.

- Will the Energy Source voltage always be above the circuitry voltage?
  Yes, we are planning to use VBAT, VBAT_OK and VBAT_OV pins of PMIC for setting the battery undervoltage and overvoltage threshold for the indication.

# Miscellaneous Updates

- As per feedback from the professor, the Gantt chart has been updated with future task to represent the project timelines more accurately. The major checkpoints have been assigned to the team and the smaller tasks under each heading will be broken down for modularity and assigned to individual members.
  Gantt chart git link
- The work on separate vs common busses for both I2C and SPI busses will be taken up in the following week. As per our current design, common busses will lead to difficulty in load power management as one of the ICs is required to be on for longer than the others.